Schema.org Extensions for IoT

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***Abstract*—The Web of Things depends on common semantic vocabularies in order to deliver broad interoperability. The work on Schema.org extensions for IoT provides a framework for extending Schema.org to provide these semantic vocabularies. By extending Schema.org, we enable an open, royalty free public resource and a community process to develop and maintain these vocabularies. The current meta-model is well aligned with the W3C Web of Things architecture and Thing Description format, and is used to create semantic definitions for annotation of Thing Description instances. Prototype semantic definitions have been used in WoT plugfests to provide a semantic layer for discovery and application integration. We are currently working on developer tools and ways of integrating the definitions into Schema.org in a way that the existing ecosystem can make use of. This paper summarizes recent progress in creating and deploying these extensions, and presents a roadmap for future development with issues and proposed direction.**

***Keywords*— Semantic Interoperability, iot.schema.org, Web of Things, JSON-LD, RDF, Linked Data**

Problem Description

The Internet of Things (IoT) digitalizes physical world by connecting physical devices to Internet and promises a new class of applications based on this digitalization. Applications based on data coming from physical world are possible but in practice are not easily achievable. First, there is lack of a common access to data residing in multiple domains. Second, semantics of data that is generated by heterogenous devices and systems is often unclear. Both reasons make the IoT data difficult for use.

W3C Web of Things[1](WoT) activities aim to counter the fragmentation of the IoT. The W3C WoT provides a common access to data from different domains. But in order to deliver broad interoperability, the W3C WoT depends on common semantic vocabularies. The question is what semantic models are best suited for broad interoperability at the application level. There exist various semantic models, ranging from simple taxonomies up to complex ontologies; and further, from closed vocabularies up to open standardized models. Schema.org[2] is a collaborative, community activity with a mission to create, maintain, and promote schemas for structured data on the Internet. The W3C has started a Community Group on *Schema.org extensions for IoT*[3] in order to contribute a framework for providing semantic vocabularies for WoT and other Web applications. In this paper we refer to the extension of Schema.org for the Internet of Things as iot.schema.org, though it is expected that the work will be fully integrated into Schema.org. iot.schema.org is an open, publicly available repository of semantic definitions for connected things and their data. There are many diverse connected devices and many standards for communication with connected devices. The goal of iot.schema.org is to provide semantic definitions for things regardless of communication interface of devices. However, the goal is not to invent new semantic models. Instead iot.schema.org approach integrates and reuses other ontologies and vocabularies (e.g., OCF Models[4], Open Mobile Alliance[5], oneM2M Schemas[6]

[1] https://www.w3.org/WoT/WG/
[2] https://www.w3.org/community/iotschema/
[3] https://schema.org/
[4] https://oneiota.org/documents

etc.). The approach is open, organic and community based. By extending Schema.org, we enable a royalty free public resource for IoT semantic vocabularies and a community process to develop and maintain these vocabularies. Schema.org is the most successful semantic model, which is used today by millions of Web pages. Following the Schema.org approach, we enable a simple yet powerful semantic model to be used by WoT application developers.

iot.schema.org Model

The model of iot.schema.org revolves around the notion of thing's capabilities. Connected things expose simple "traits" and "skills". A Capability is an abstraction of something a connected thing can do, like measure temperature or switch on and off. Figure 1 shows the Capability model of iot.schema.org. A Capability has some related Interactions. An Interaction Pattern describes an affordance to the capability, which may be to read or write a value, or perform a complex action like smoothly changing the brightness of a light bulb. An Interaction can be a Property, Event or an Action. Data Schema descriptions contain data types, units, minimum and maximum values, and other information about the data model. Interactions exchange items specified by Data Schema. Additionally, the iot.schema.org semantic model includes *Feature of Interest* concepts that can associate Capabilities, Interactions, and Data elements, and their instances, with features in the physical world, such as machine parts or locations.

iot.schema.org specifications are machine interpretable descriptions, provided in JSON-LD[7] SHACL[8] formats.

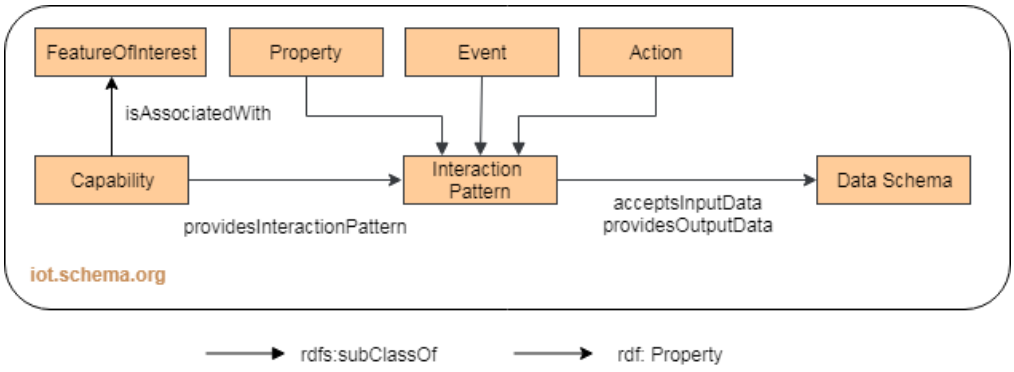

Figure 1: Capability Model of iot.schema.org

In April 2019 we proposed an update to the current model of iot.schema.org. The change introduces additional relations between a Capability and its Interactions, as well as relations between Interactions and its Data. The new relations are sub properties of relations `providesInteractionPattern`, and `acceptsInputData/providesOutputData`, respectively. Similar, we have created additional relations for data types and unit codes. The new semantic model still adheres to the original Capability model but is better aligned with the Schema.org model. Figure 2 depicts an example of `AirConditioner` Capability specified according to the updated iot.schema.org model. The Capability has eight Interactions (`TurnOn`, `TurnOff`, `RunMode`, `SwichStatus` and others). `Temperature` and `TargetTemperature` are two

[5] https://github.com/OpenMobileAlliance/lwm2m-registry
[6] http://www.onem2m.org/technical/xml-schemas
[7] https://json-ld.org/
[8] https://www.w3.org/TR/shacl/

Interactions that are shared between `AirConditioner` and two other Capabilities (i.e., `TemperatureSensing` and `Thermostat`). Further on, Figure 2 shows how the data including data types and unites have been specified for each Interaction.

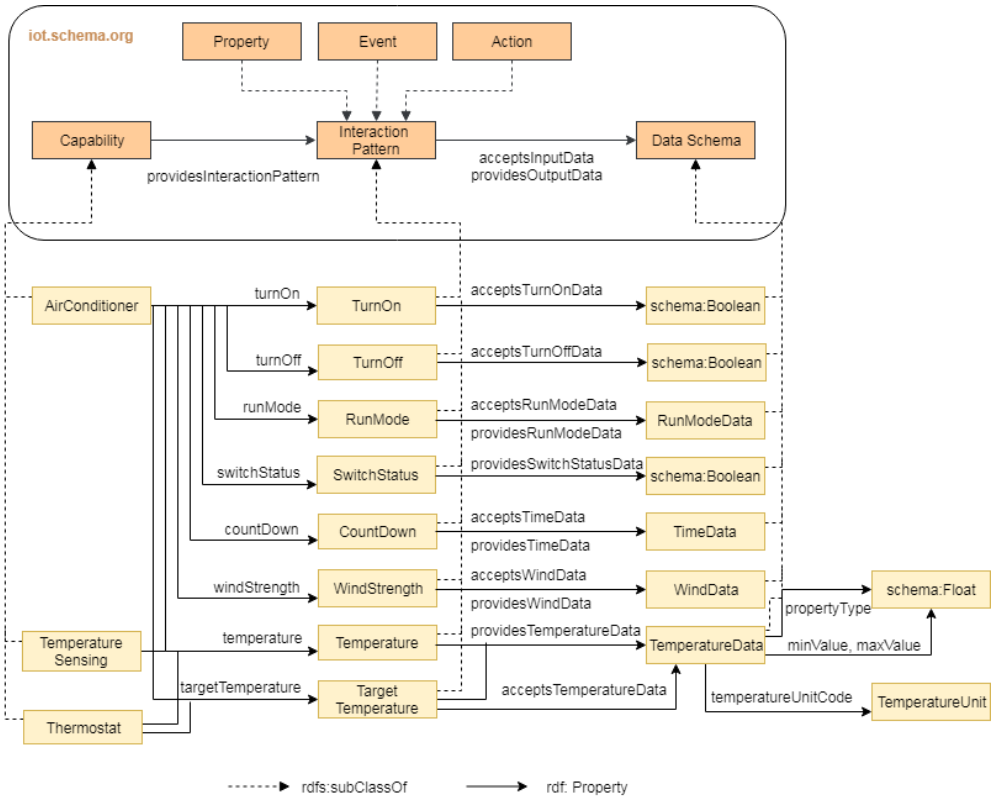

Figure 2: An Example of iot.schema.org Capabilities in the Updated Model

Conclusion and Roadmap

In order to deliver broad interoperability, the upcoming W3C standard on Web of Things depends on common semantic vocabularies. This is the reason why W3C has started a Community Group on *Schema.org extensions for IoT*. In this group we are working on iot.schema.org as an extension of Schema.org for the IoT. The contribution is an open, publicly available repository of semantic definitions for connected things and their data.

Regarding the roadmap, we have identified several activities. First, we have to update the existing semantic definitions according to the newly proposed model (see the previous Section). This will make iot.schema.org definitions browsable in Schema.org-like manner. Second, we will develop and document pattern, practices and tools for creating and using definitions. This will enable iot.schema.org definitions to be easier used by domain experts. Further on, we have to make effort in integration of existing semantic models such as, for example, Project Haystack, Brick Schema, W3C Linked Building Data and others, with the model of iot.schema.org. Finally, we will continue the work on the project *iotschema for Node-RED*, where we provide semantic definitions from iot.schema.org integrated into Node-RED[9] tool. In this activity we enable WoT

[9] https://nodered.org/

application developers, who are not necessarily semantic experts, to easily use iot.schema.org definitions in a widely used tool for developing IoT applications.